The Charge Form Factor of the Neutron at Low Q^2

- Introduction/Motivation

- BLAST Experiment

- Results and Discussion

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PANIC05, Santa Fe

The Charge Form Factor of the Neutron at Low Q^2

High quality data for nucleon and deuteron structure by means of *spin-dependent electron scattering*

Pol. H

$$\vec{p}(\vec{e},e') \quad \vec{p}(\vec{e},e'p) \quad \vec{p}(\vec{e},e'\pi^+)n, \vec{p}(\vec{e},e'p)\pi^o, \vec{p}(\vec{e},e'n)\pi^+$$

Gen. GDH G^p_E/G^p_M N-Δ: C2/M1

Vect-Pol. D

$$\vec{d}(\vec{e},e') \quad \vec{d}(\vec{e},e'p) \quad \vec{d}(\vec{e},e'n) \quad \vec{d}(\vec{e},e'd)$$

G^n_M D-state G^n_E T^e_{11}

Tens-Pol. D

$$\vec{\vec{d}}(e,e'd) \quad \vec{\vec{d}}(e,e'p)$$

T_{20} D-state

Scientific Motivation

- Nucleon form factors provide basic information on nucleon structure

- G^n_E is the least known among the nucleon form factors, with errors of typically 15-20%

- Low-Q^2 region is a testing ground for QCD and pion-cloud inspired and other effective nucleon models

- G^n_E related to neutron charge distribution

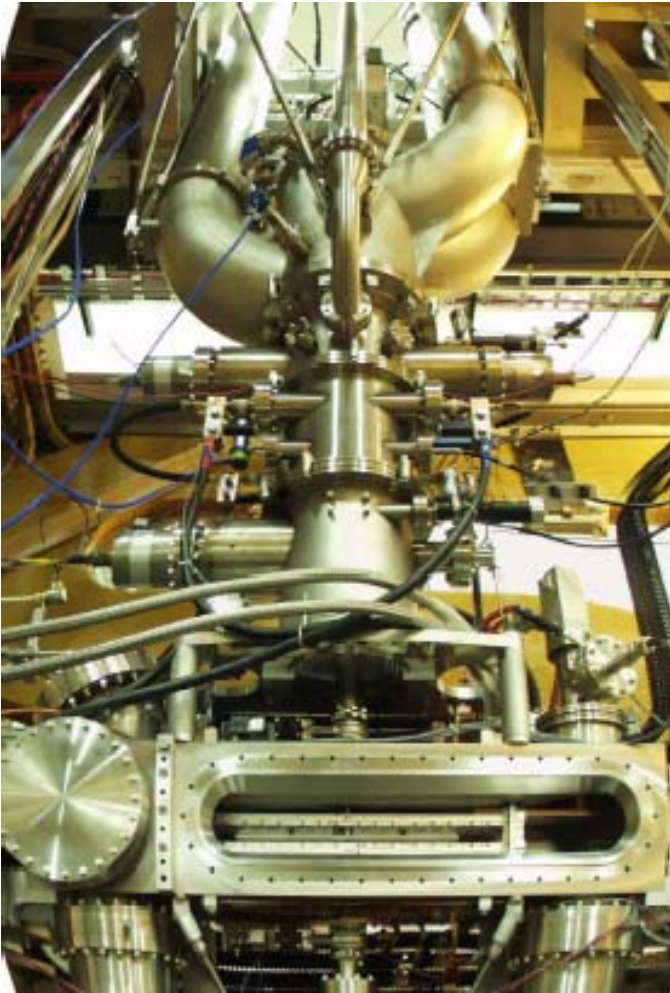- Precise knowledge of G^n_E is essential for parity violation experiments

MIT-Bates Linear Accelerator Center
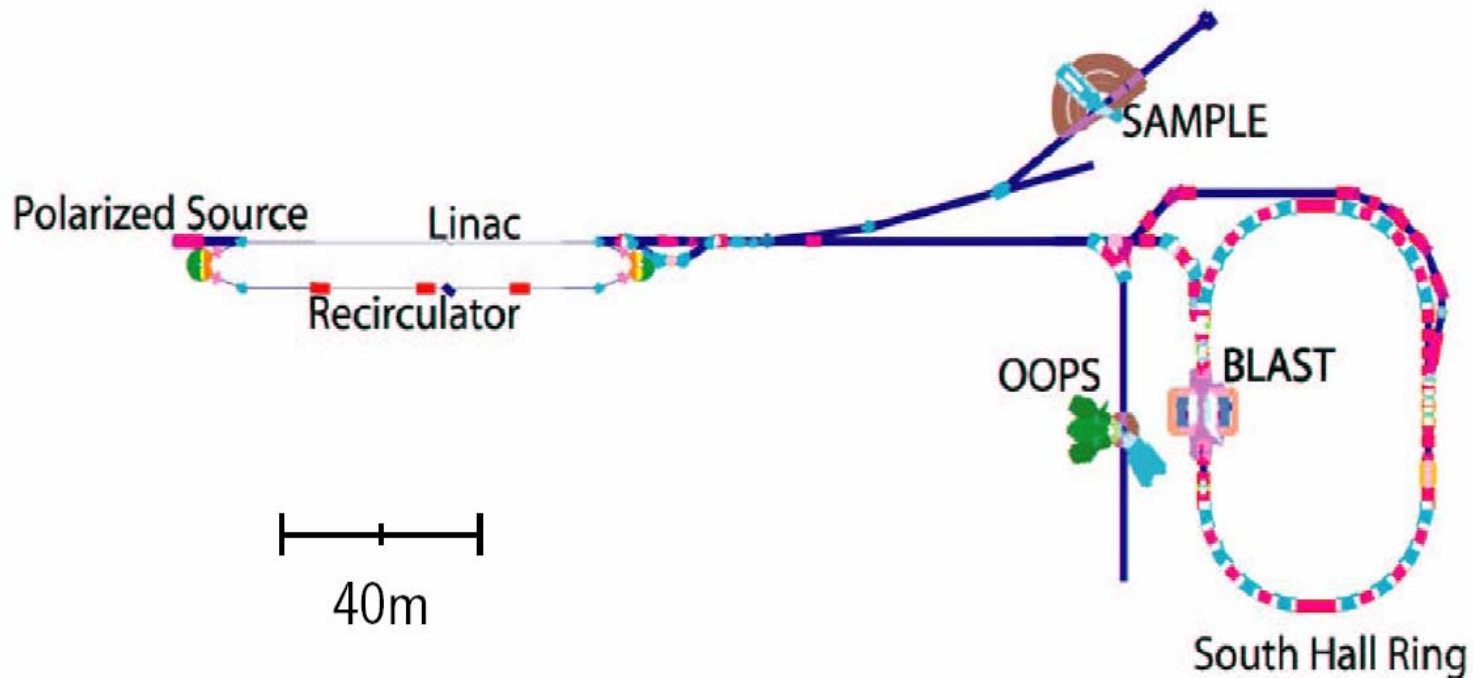
- **Linac:** 2×500 MeV
- **Beam:** 850 MeV / I_{max} = 225 mA / P_e = 65 %
- **SHR:** Siberian Snake + Compton Polarimeter
- **Target**: Internal Target = Atomic Beam Source
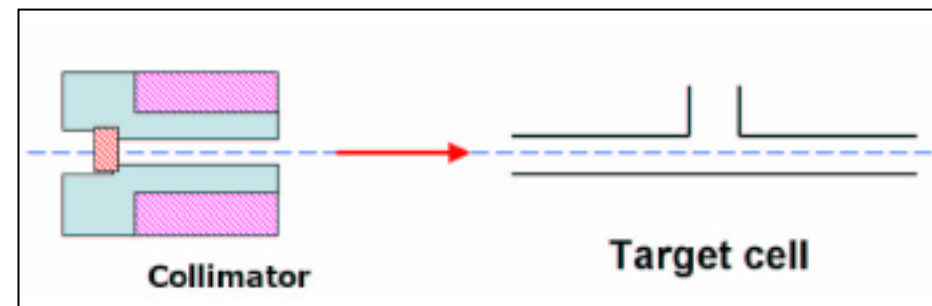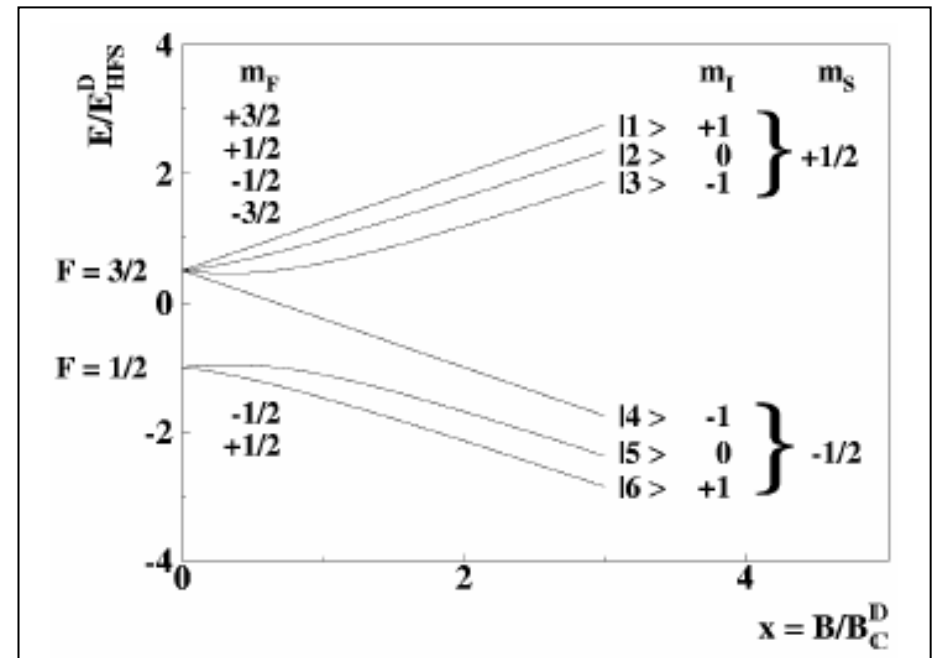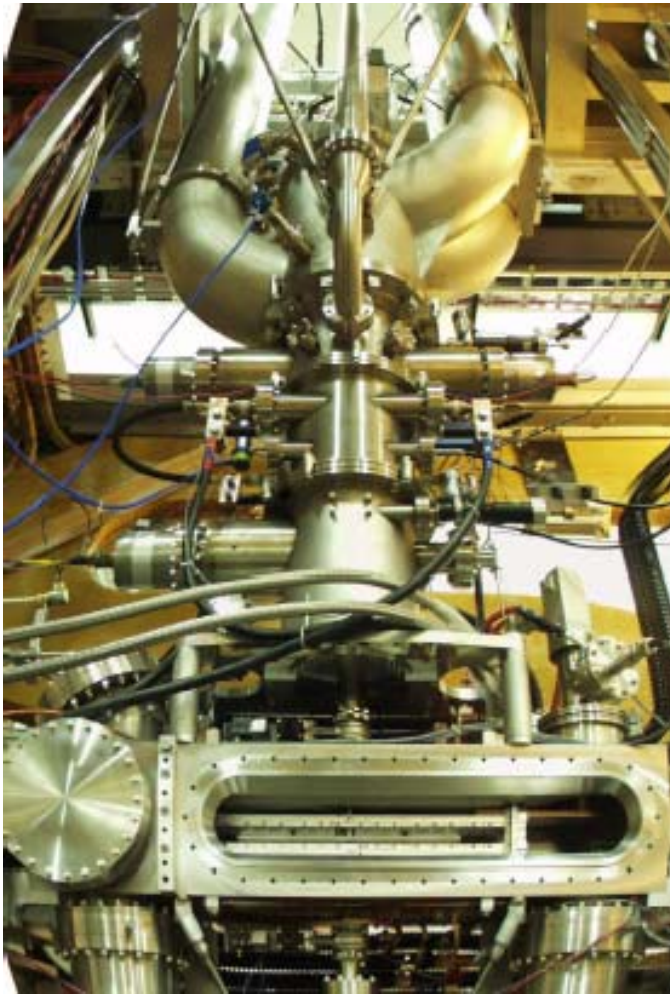
Atomic Beam Source

- Isotopically pure H or D
  - Vector Polarized H
  - Vector and Tensor D

- Target Thickness/Luminosity
  - Flow 2.2×10^{16} atoms/s
  - Density 6×10^{13} atoms/cm^2
  - Luminosity 6×10^{31} cm^{-2}s^{-1}
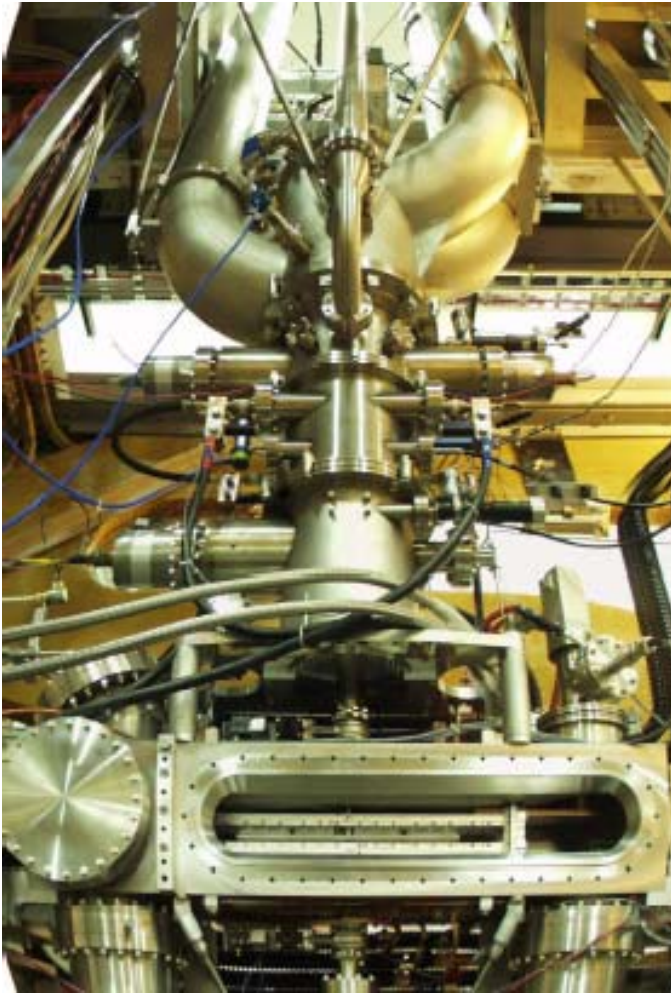
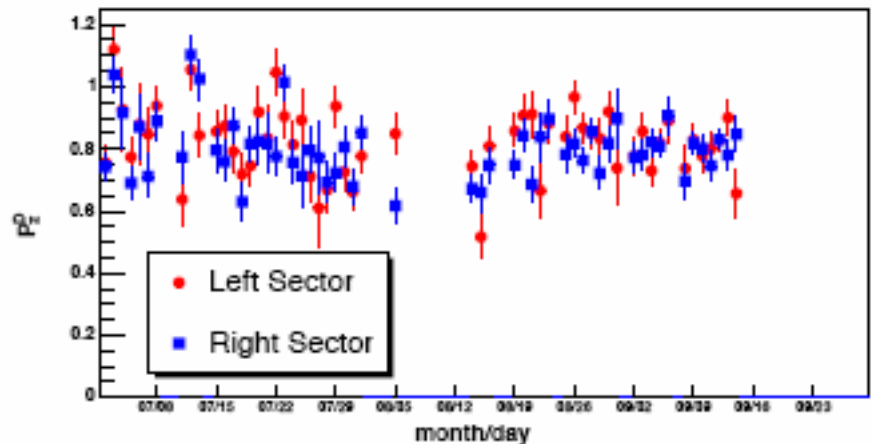- Target Polarization typically 70-80%

Collimator   Target cell
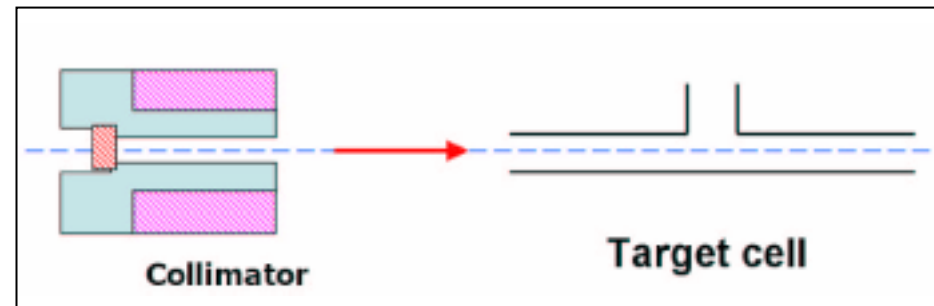
Atomic Beam Source

Atomic Beam Source

- Quasielastic $^2\vec{H}(\vec{e},e'n)p$
- Beam-Target Asymmetry
- $A^v_{ed}(\exp) = h \cdot P_z \cdot A^v_{ed}(\text{th})$
- $\langle hP_z \rangle = 0.567 \pm 0.006$

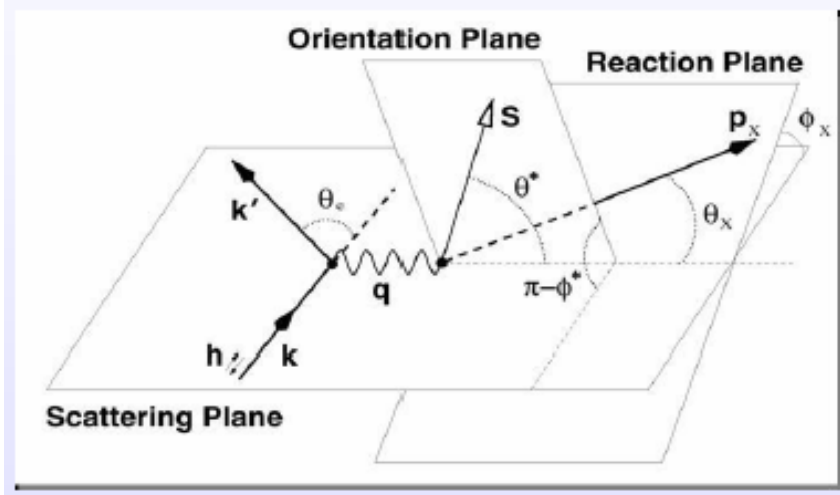 $\langle P_z \rangle = 0.85 \pm 0.04$

  $\langle h \rangle = 0.67 \pm 0.04$

BLAST Detectors

- Left-Right symmetry
- Large Acceptance
  - $0.1 < Q^2/(GeV/c)^2 < 1.0$
- Coils: $B = 3.8$ kG
- Drift Chambers
  PID, tracking
  - $\delta\theta \approx 0.5°$, $\dfrac{\delta p}{p} \approx 3\%$

- Cerenkov Counters
  - e, π separation
- Scintillators
  - TOF, PID, trigger
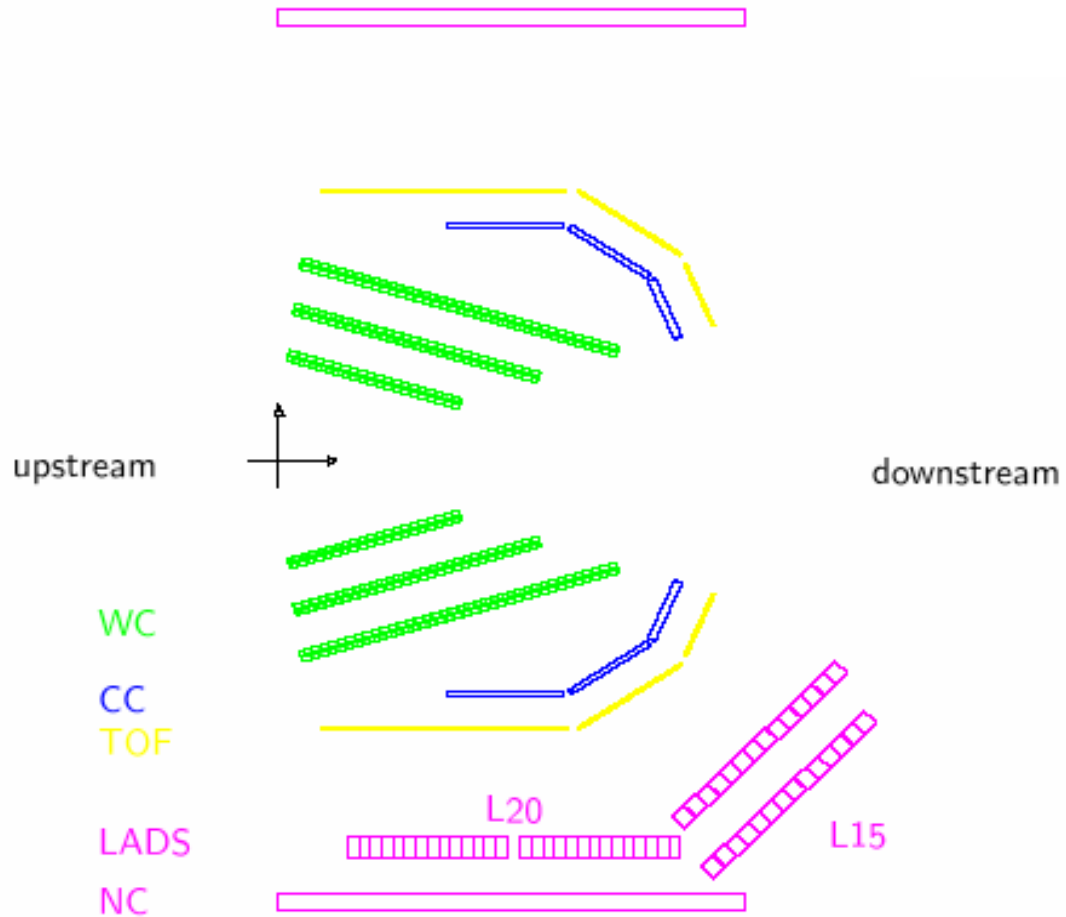- Neutron Counters
  - Neutron ToF
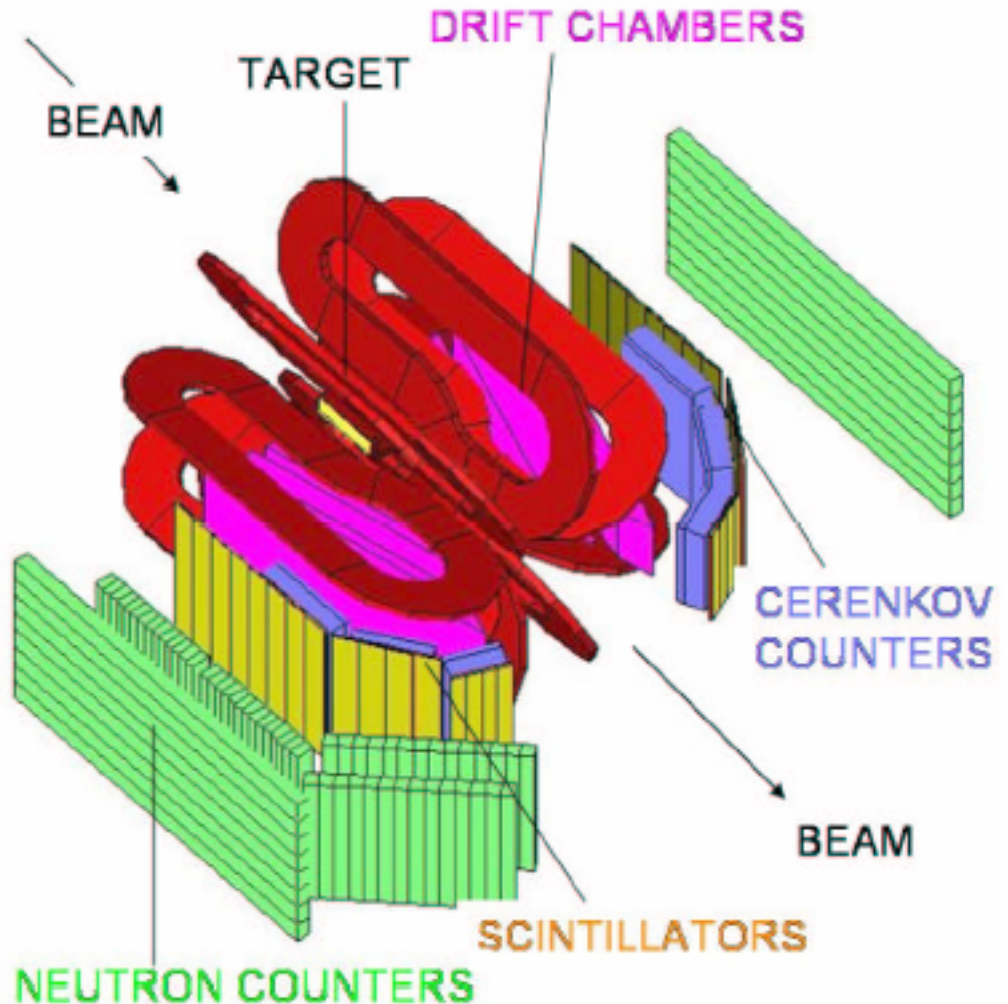
Kinematics and Observables

- Electrodisintegration of the Deuteron
- Quasi-elastic $^2H(e,e'n)$
- Beam + Target Polarized

$$\frac{d\sigma}{d\Omega_e dE_{e'} d\Omega_{CM}} = S_0(1 + P_d^V A_d^V + P_d^T A_d^T + h(A_e + P_d^V A_{ed}^V + P_d^T A_{ed}^T))$$

$$A_{ed}^V = \frac{a G_M^{n\,2} \cos\theta^* + b G_E^n G_M^n \sin\theta^* \cos\phi^*}{c G_E^{n\,2} + G_M^{n\,2}} \approx a\cos\theta^* + b\frac{G_E^n}{G_M^n}\sin\theta^* \cos\phi^*$$

upstream
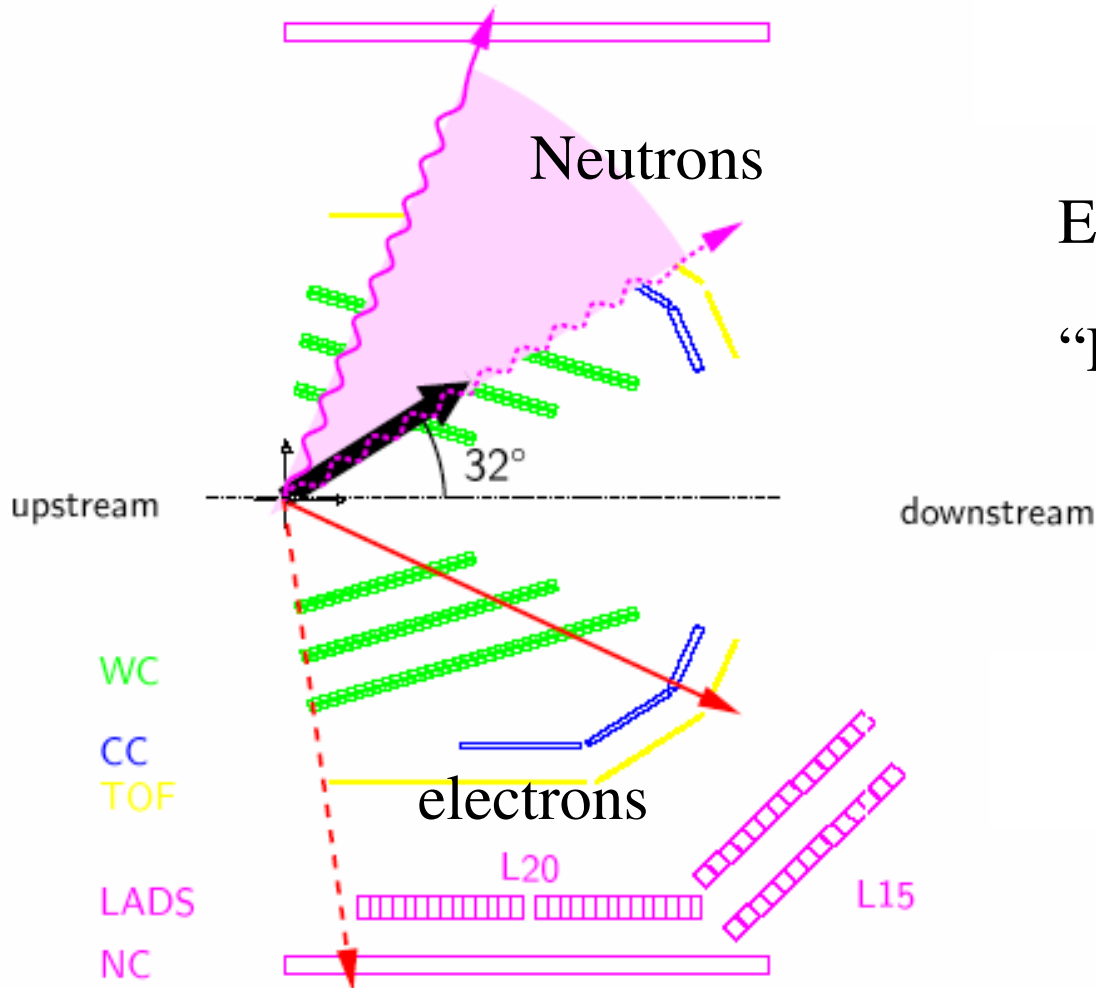
downstream

WC

CC
TOF

L20

LADS

L15

NC

Experimental Layout

Neutrons

Electron - Right Sector

"Parallel" Kinematics

$$\theta^* \approx 0$$

32°

upstream

downstream

WC

CC

TOF

LADS

NC

electrons

L20

L15

Experimental Layout

electrons

neutrons

upstream

downstream

$32°$

WC

CC
TOF

LADS

NC

L20

L15
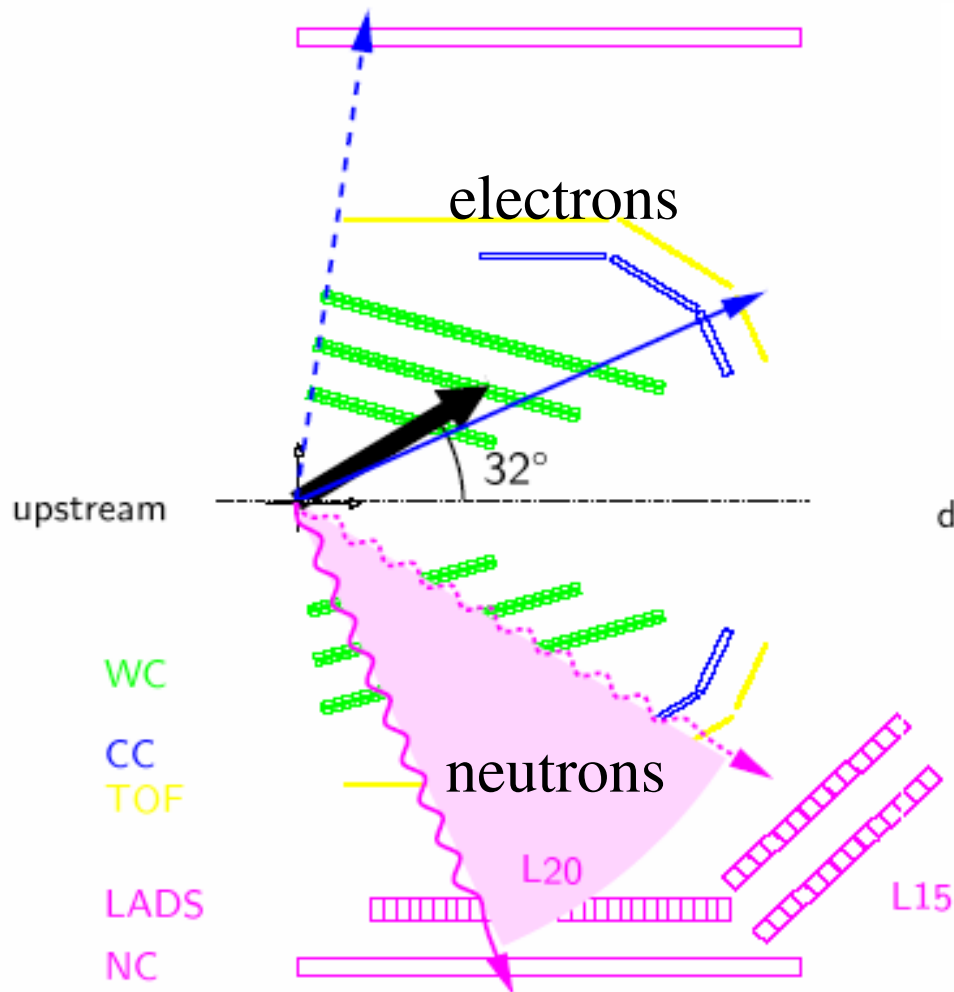
Electron - left sector

"Perpendicular" Kinematics

$\theta^* \approx 90$

Blast data

- 3 MC integrated charge delivered to BLAST

- Programs for polarized hydrogen and vector/tensor polarized deuterium

- Deuterium run May-October 2004, spin angle 32º
  450 kC charge (169 pb^{-1}), P_z=85%, P_{zz}=66%

- Deuterium run March-May 2005, spin angle 47º
  550 kC charge (150 pb^{-1}), P_z=70%, P_{zz}=54%

- Preliminary data will be presented for 2004 run

Invariant Mass and Time of Flight

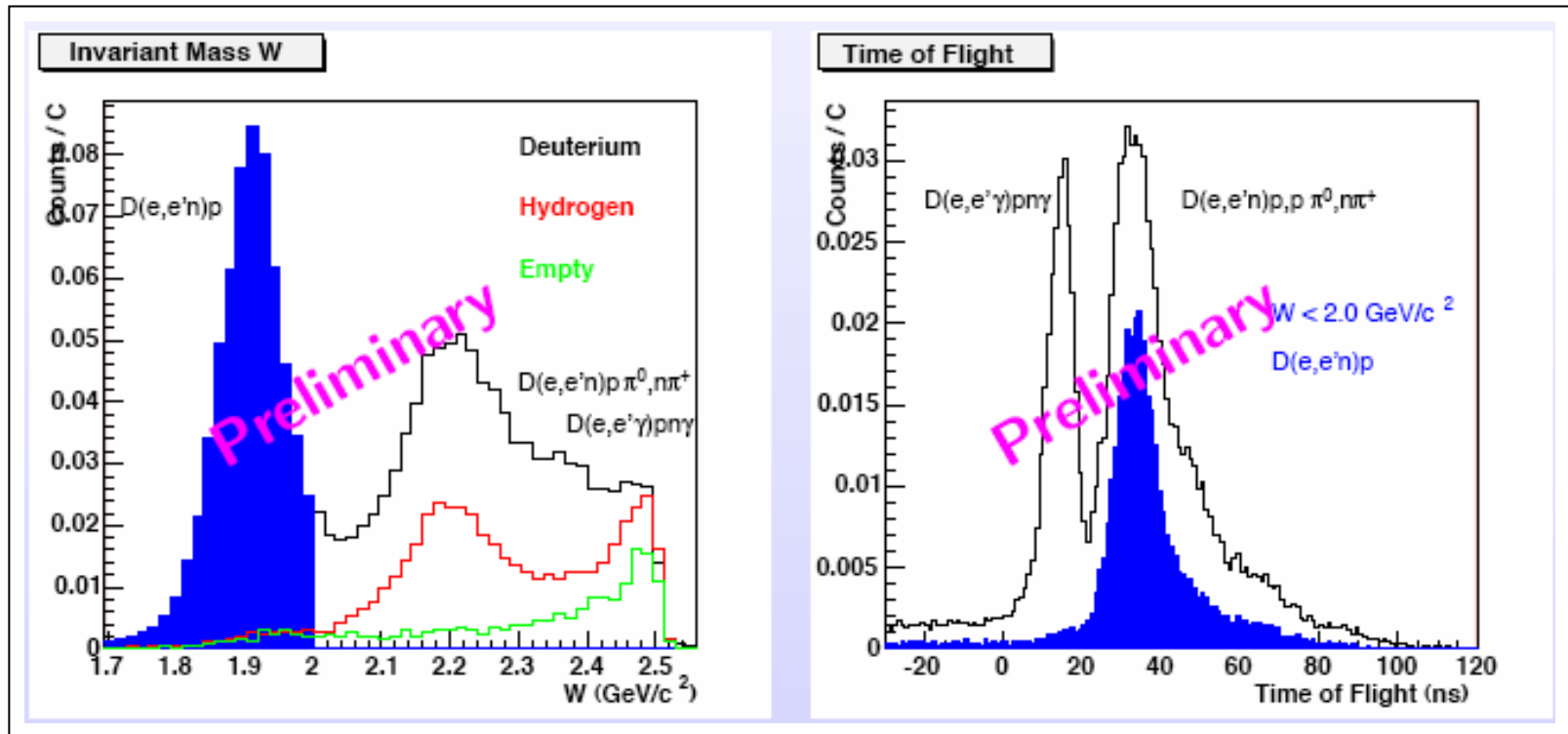- Very clean quasi-elastic $^2H(e,e'n)p$ spectrum

- Highly efficient proton veto (Wire Chambers)
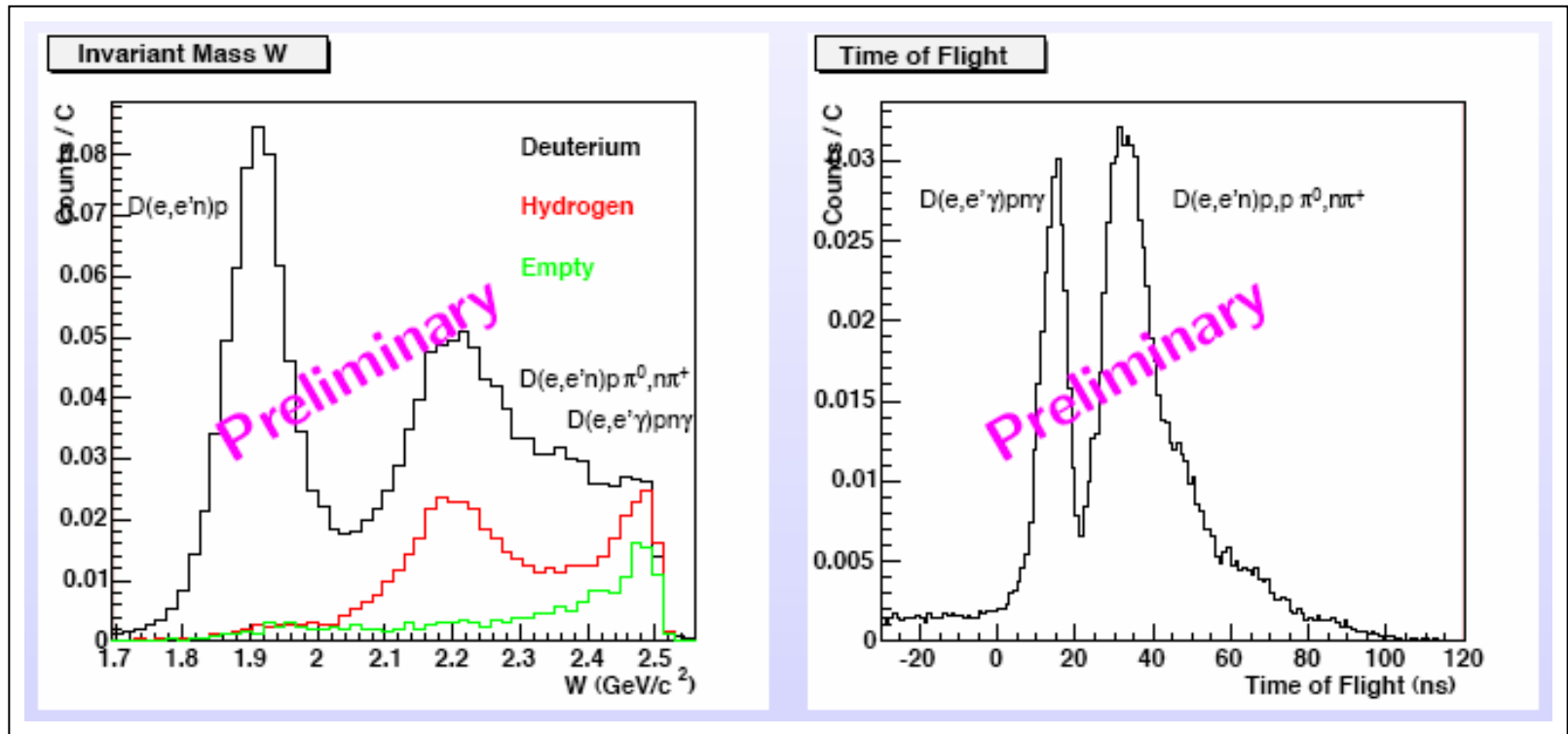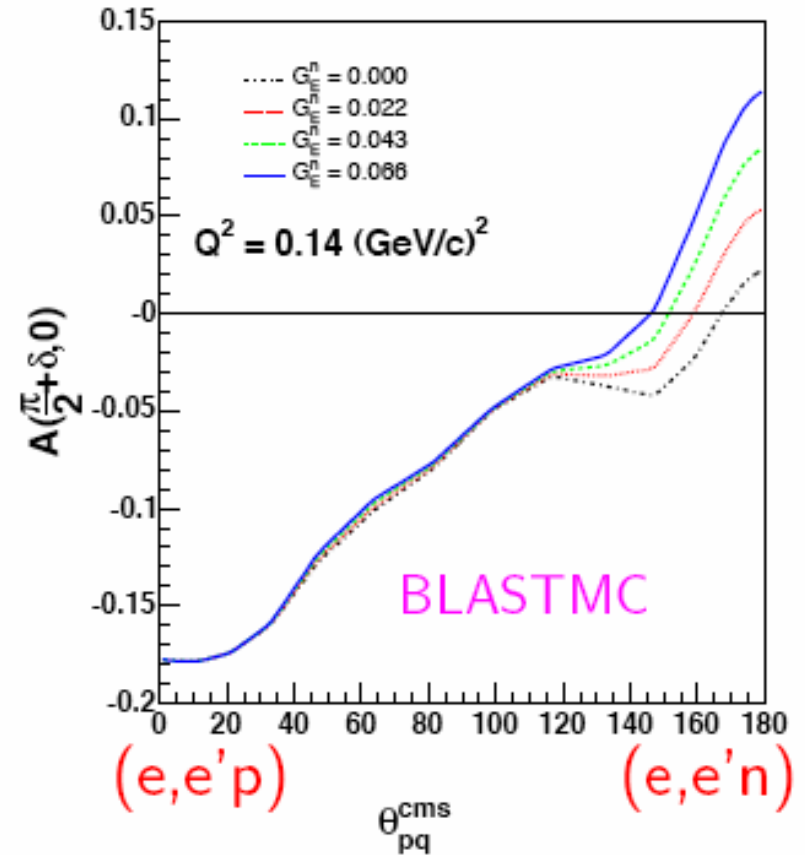
Invariant Mass and Time of Flight

- Very clean quasi-elastic $^2H(e,e'n)p$ spectrum

- Highly efficient proton veto (Wire Chambers)

Extraction of G^n_E

- Quasielastic $^2\vec{H}(\vec{e},e'n)p$
- Full Monte Carlo Simulation of the BLAST experiment
- Deuteron Electrodisintegration cross section calculations

  by H. Arenhövel
- Accounted for FSI, MEC, IC, RC
- Spin-perpendicular beam-target asymmetry $A_{ed}^V(90°,0°)$ shows high sensitivity to G^n_E

Legend:
$G^n_E = 0.000$
$G^n_E = 0.022$
$G^n_E = 0.043$
$G^n_E = 0.066$

$Q^2 = 0.14$ (GeV/c)^2

$A(\frac{\pi}{2}+\delta,0)$

BLASTMC

$(e,e'p)$ $(e,e'n)$
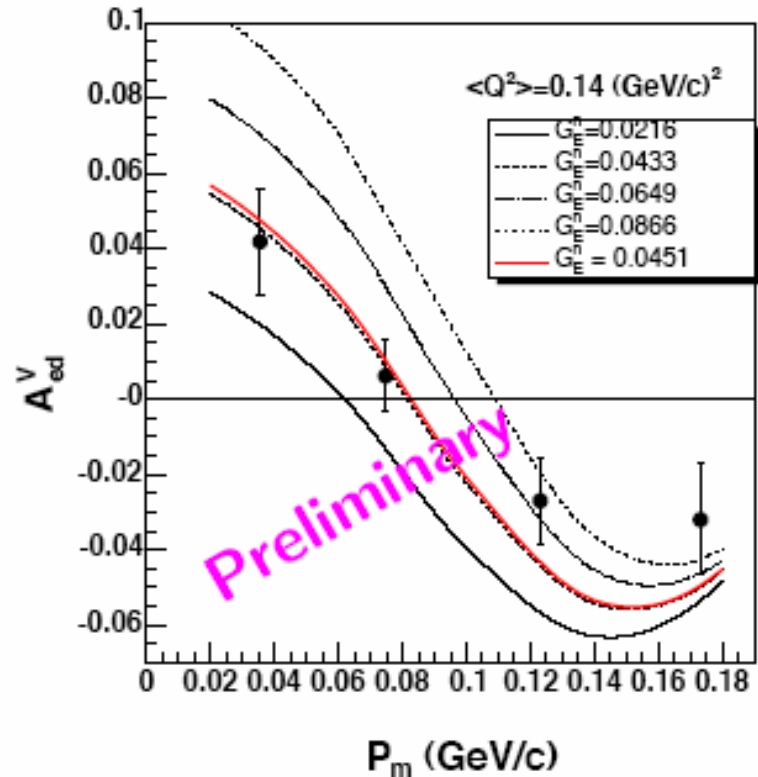
θ^{cms}_{pq}

Extraction of G^n_E

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- Accounted for FSI, MEC, IC, RC
- Spin-perpendicular beam-target asymmetry $A_{ed}^V(90^o,0^o)$ shows high sensitivity to G^n_E
- Compare measured A_{ed}^V with BLASTMC, varying G^n_E

$\langle Q^2 \rangle = 0.14$ (GeV/c)^2

- $G^n_E = 0.0216$
- $G^n_E = 0.0433$
- $G^n_E = 0.0649$
- $G^n_E = 0.0866$
- $G^n_E = 0.0451$

Preliminary

A_{ed}^V

P_m (GeV/c)

Systematic Errors

- **Uncertainty of target spin angle**   **5%**
    - 12% per degree
- **Beam-target polarization product**   **2.5%**
- **Radiative effects**   **<1.0%**
    - Small helicity dependency
- **Uncertainty of G^n_M**   **1.5%**
- **Model dependency**   **<3%**
    - Effect of potential negligible
    - Final state interaction reliable

Total: **6.6%**
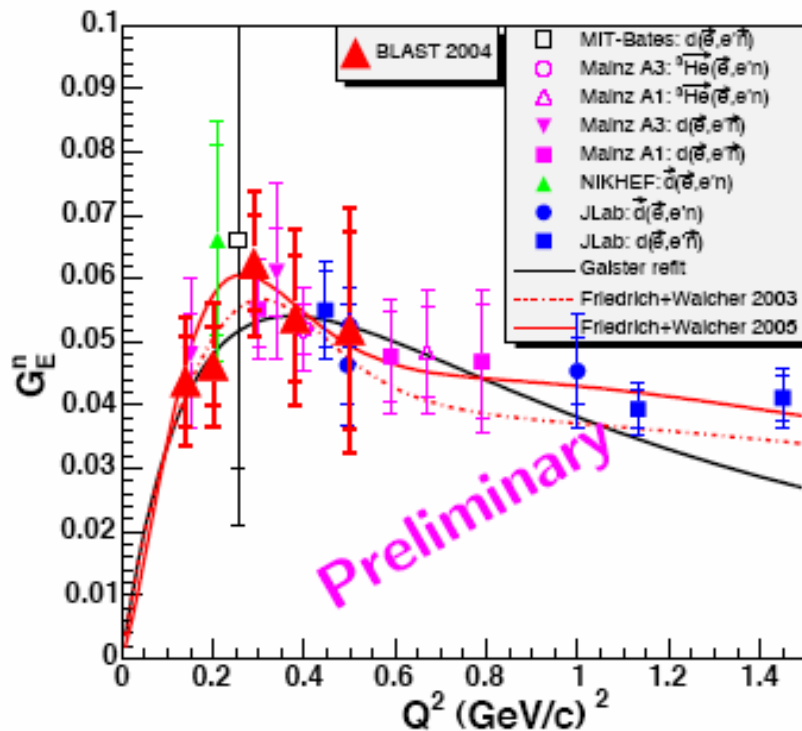
Results and Discussion
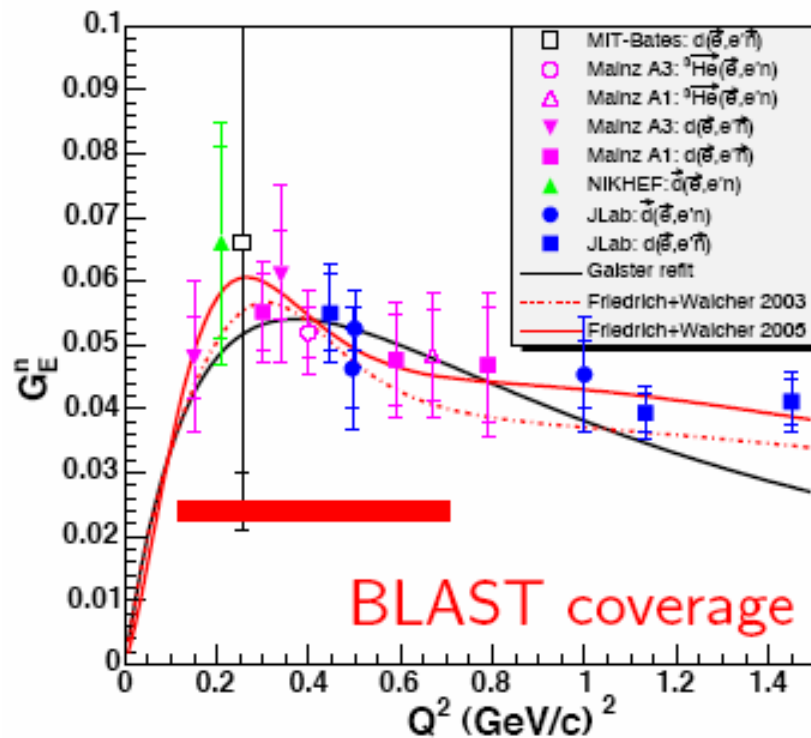
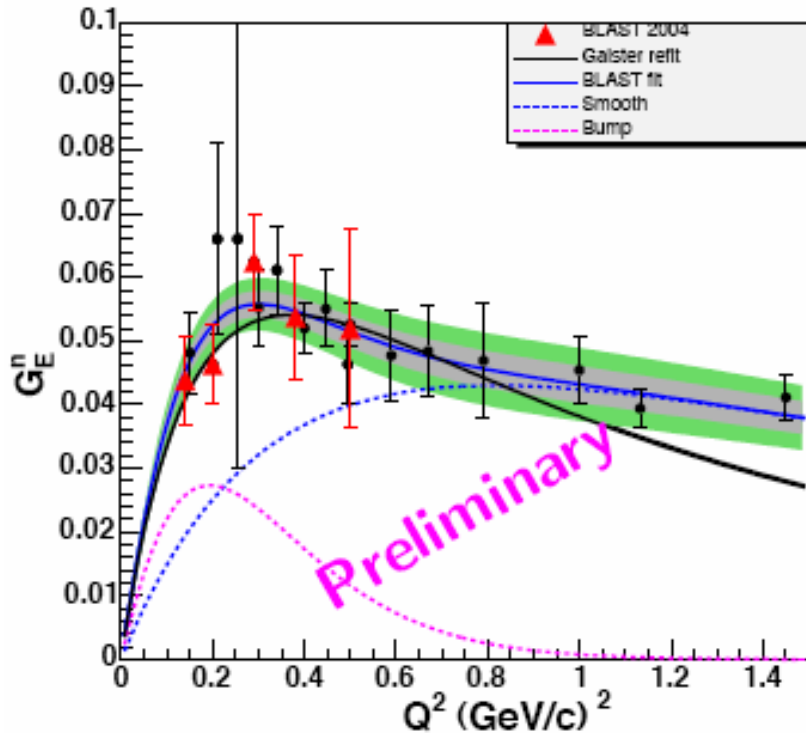- World data on G^E_n from double pol. Experiments

Results and Discussion

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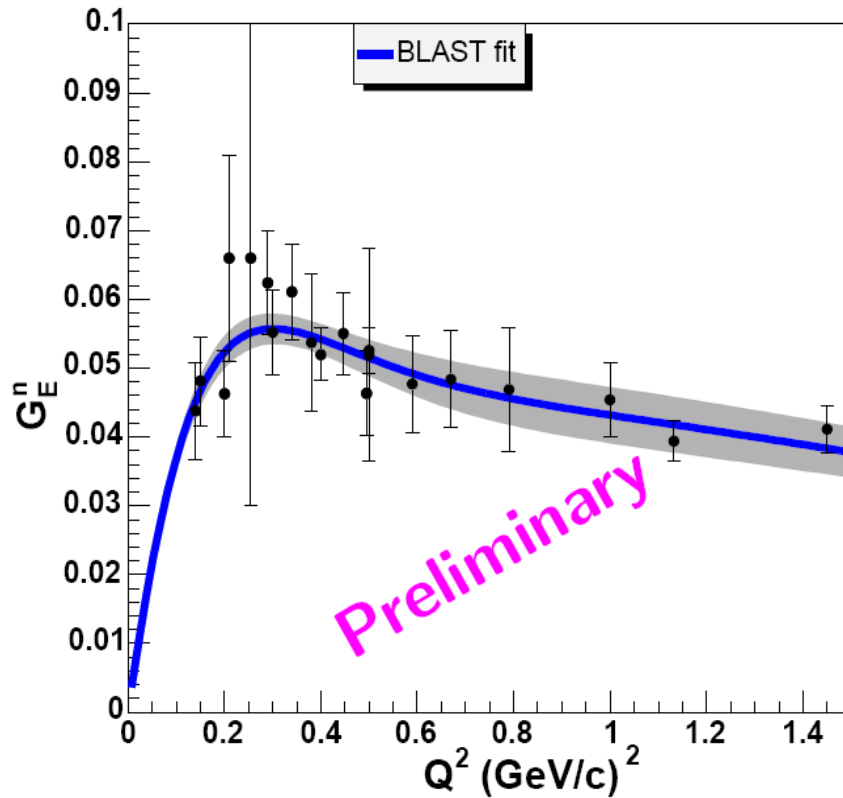- Including BLAST 2004

Results and Discussion

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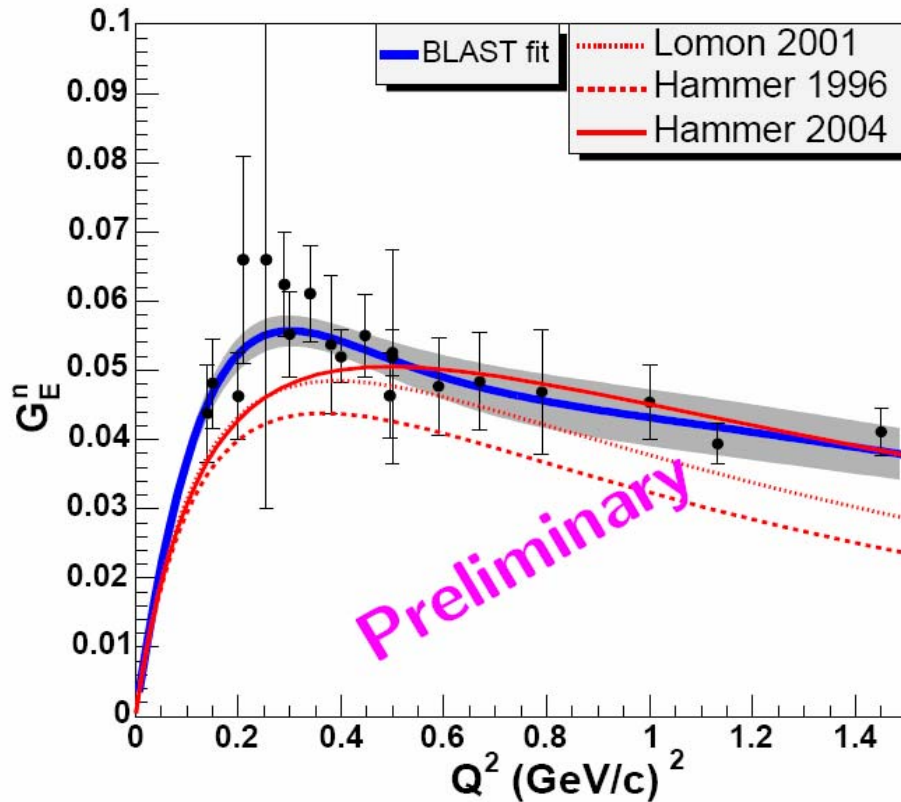- BLAST Fit
  - $<r_n^2> = -0.115$ fm^2

Nucleon Models

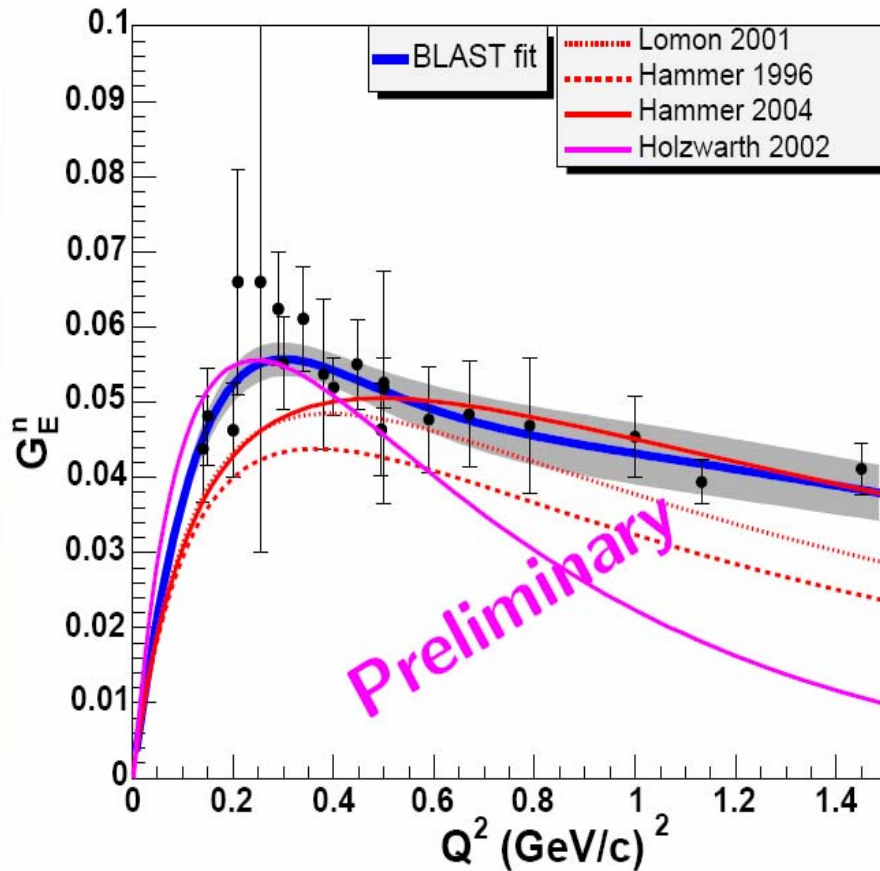- World data on G^n_E from double pol. Experiments

Nucleon Models

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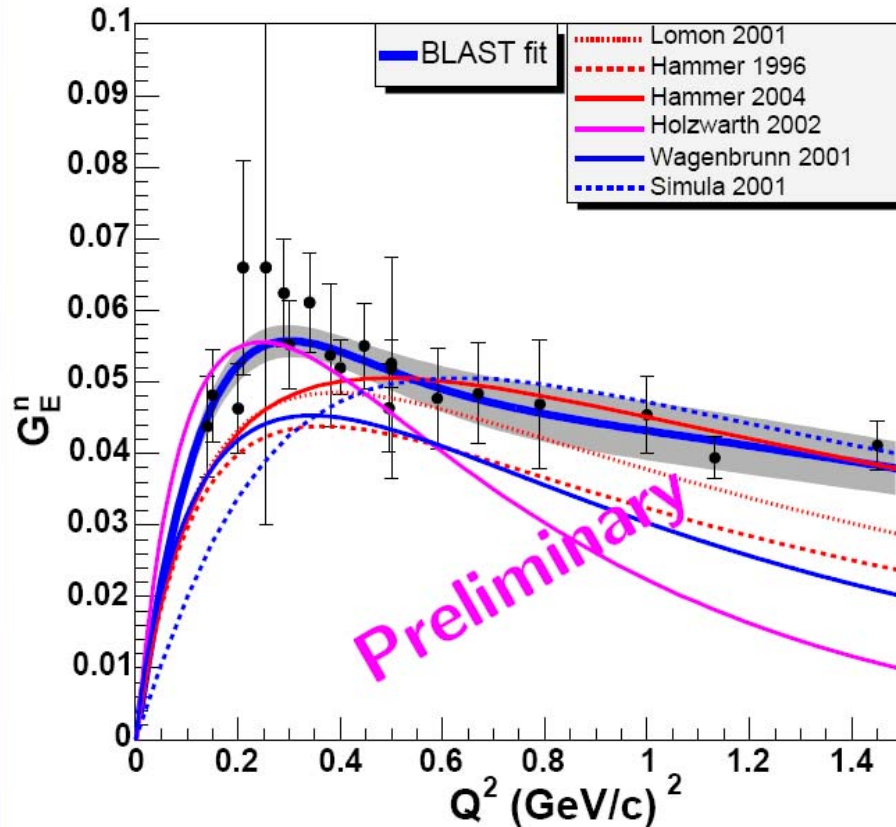- **Dispersion Theory**

Nucleon Models

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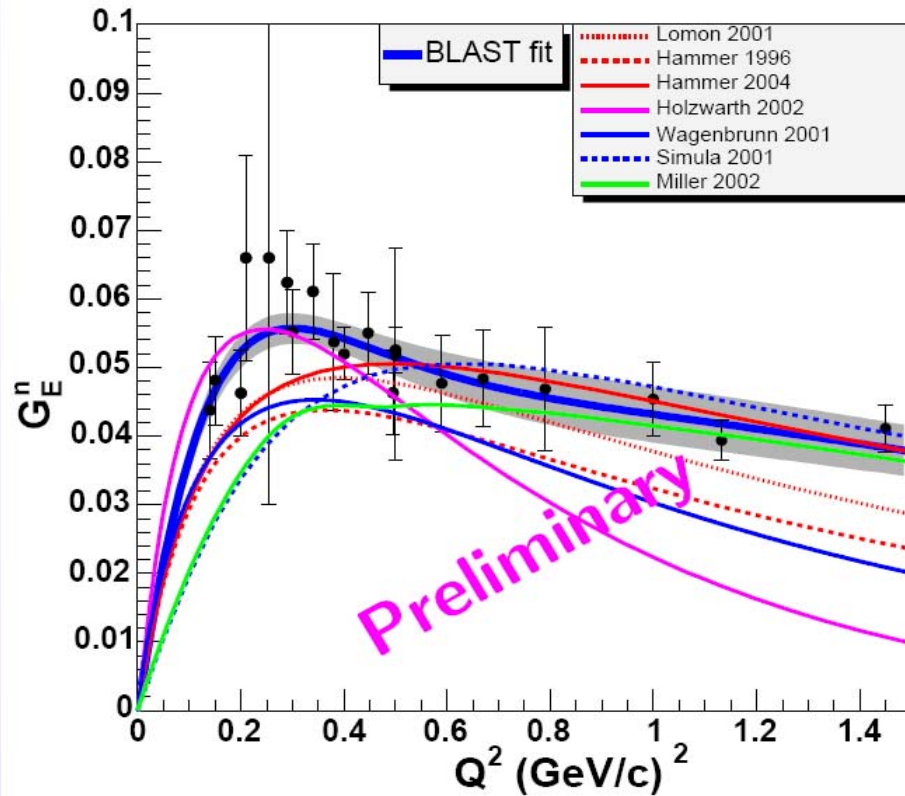- **Dispersion Theory**
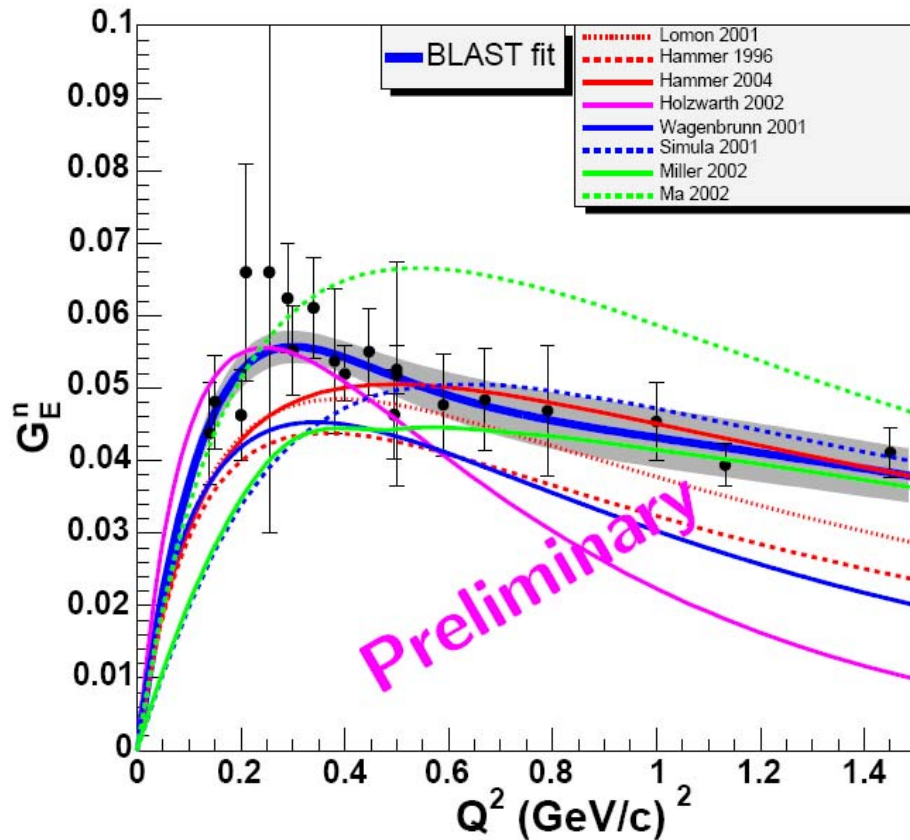- **Chiral Soliton**

Nucleon Models

- World data on G^n_E from double pol. Experiments
- **Dispersion Theory**
- **Chiral Soliton**
- **R-CQM**

Nucleon Models

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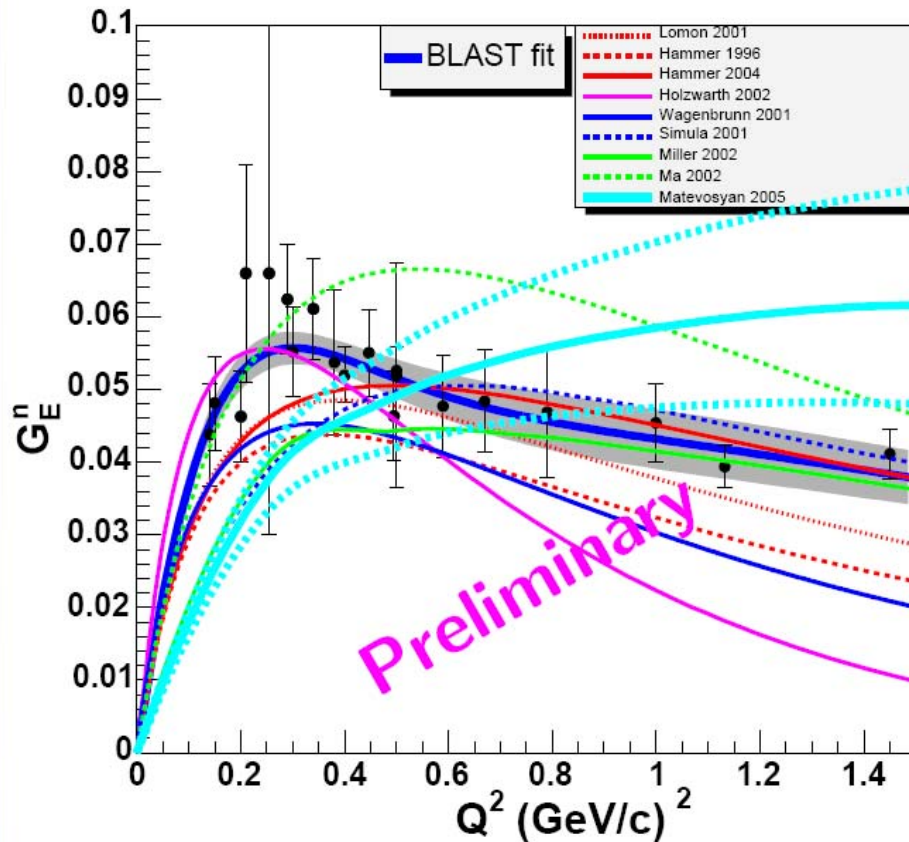- **R-CQM**
- **Cloudy bag**

Nucleon Models

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- **Chiral Soliton**
- **R-CQM**
- **Cloudy bag**
- **Diquark**

Nucleon Models

- World data on G^n_E from double pol. Experiments
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- **Chiral Soliton**
- **R-CQM**
- **Cloudy bag**
- **Diquark**
- **Lattice**

Conclusion

- Measure G^n_E with quasielastic scattering of polarized electrons from vector-polarized deuterium using BLAST at MIT-Bates

- Very small systematic errors

- G^n_E overall known to $\approx 5\%$ at $Q^2 < 1$ $(GeV/c)^2$

- Dispersion theory gives the best description

- No theory describes G^n_E at low and high Q^2 simultaneously

- Evidence for enhancement at low Q^2 - role of pion cloud?

Outlook

- Only half of the BLAST data analyzed so far, prel. results of full dataset envisioned for December 2005

- With new precision data of T_{20} from BLAST and with improved $A(Q^2)$ new attempt to G^n_E determine from G_Q

- ed elastic analysis: Mainz-Saclay discrepancy 8% in $A \Rightarrow$ factor of 2 in G^n_E
  - New measurements of $A(Q^2)$ at JLab (E-05-004) and MAMI

- Extension of G^n_E at high $Q^2 < 3.5$ (GeV/c)^2 (E-02-13)

- Proposal of BLAST@ELSA/Bonn
  Measure G^n_E for $Q^2 = 0.04\text{-}1.5$ (GeV/c)^2 with both vector-polarized ^{2}H and polarized ^{3}He